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(56) Documents Cited
GB 2263941 A GB 2114660 A WO 85/05654 A
US 5161497 A

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(54) Abstract Title

Combustion engine with internal EGR

(57) A combustion engine comprises a cylinder 10, one or more intake flow paths 12, 14 with one or more intake valves, two exhaust flow paths 16, 18 with one or more exhaust valves and means to delay the closing time of at least one exhaust valve into the induction stroke to induce internal EGR, i.e. allow exhaust gas to flow back into the cylinder 10. The inlet paths 12, 14 are configured to create swirl of the inlet charge. Obstruction means 24 is provided in one exhaust path to prevent exhaust gases flowing back along it into the combustion chamber while the second path is configured to permit reverse flow of the exhaust gases and to enhance the swirling motion of the charge in the cylinder 10. The engine may be operated using fixed or variable valve timing.

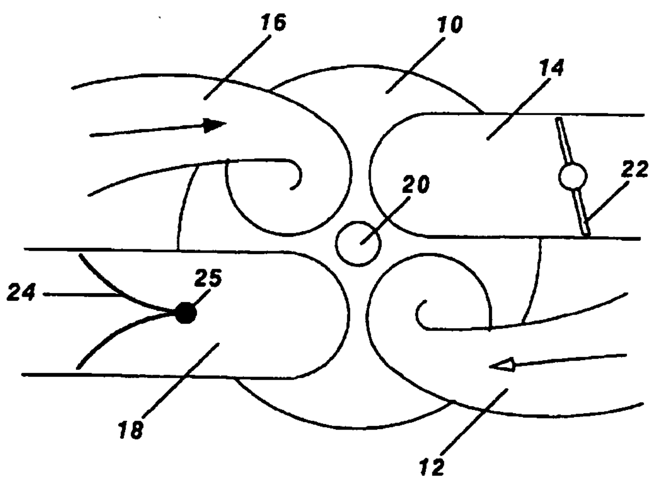

Fig.1

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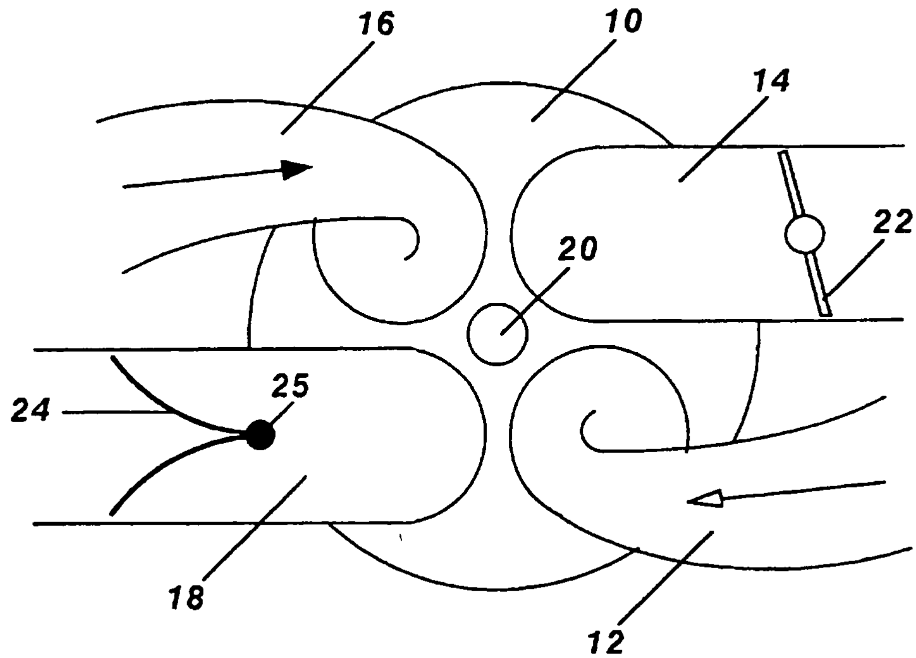


Fig. 1

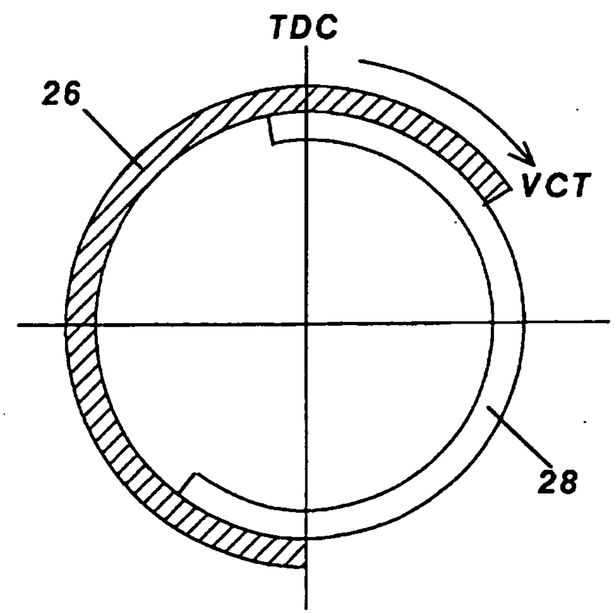


Fig. 2

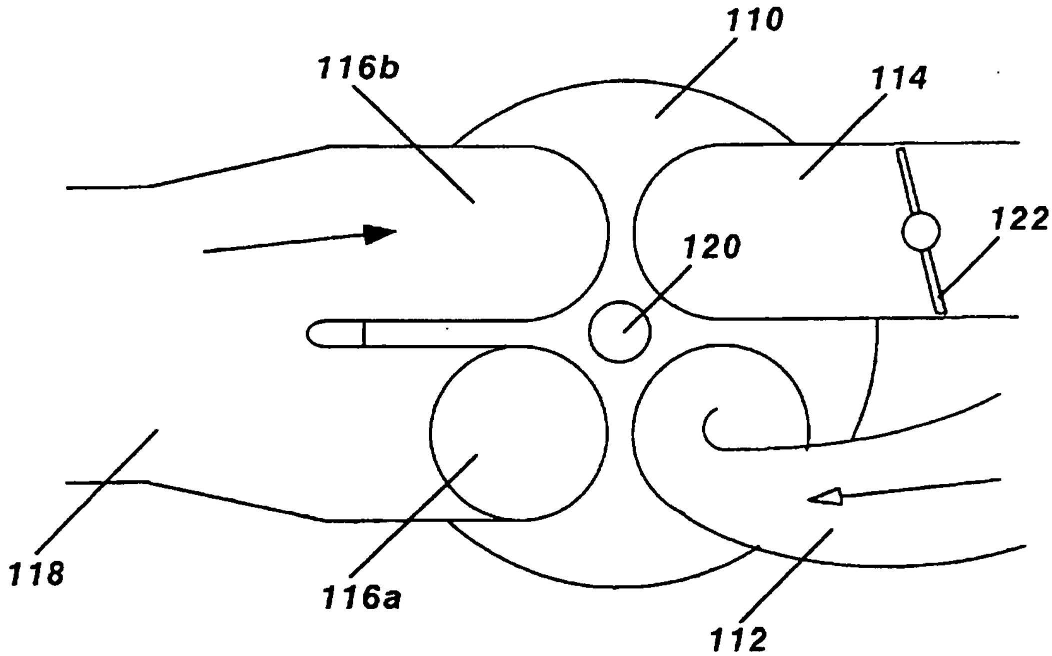


Fig.3

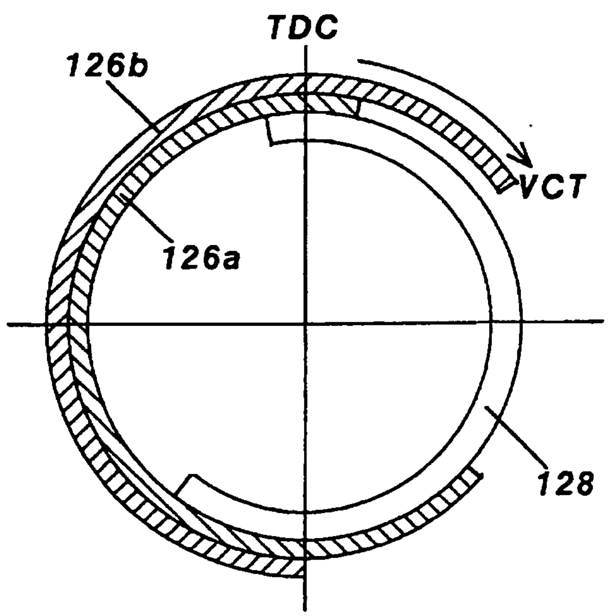
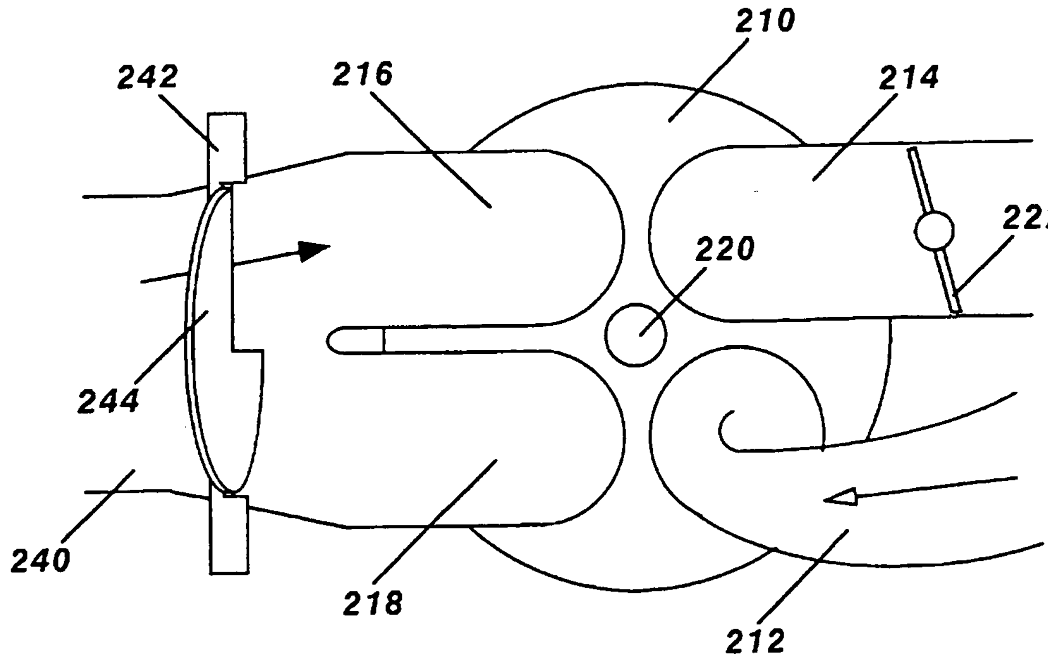
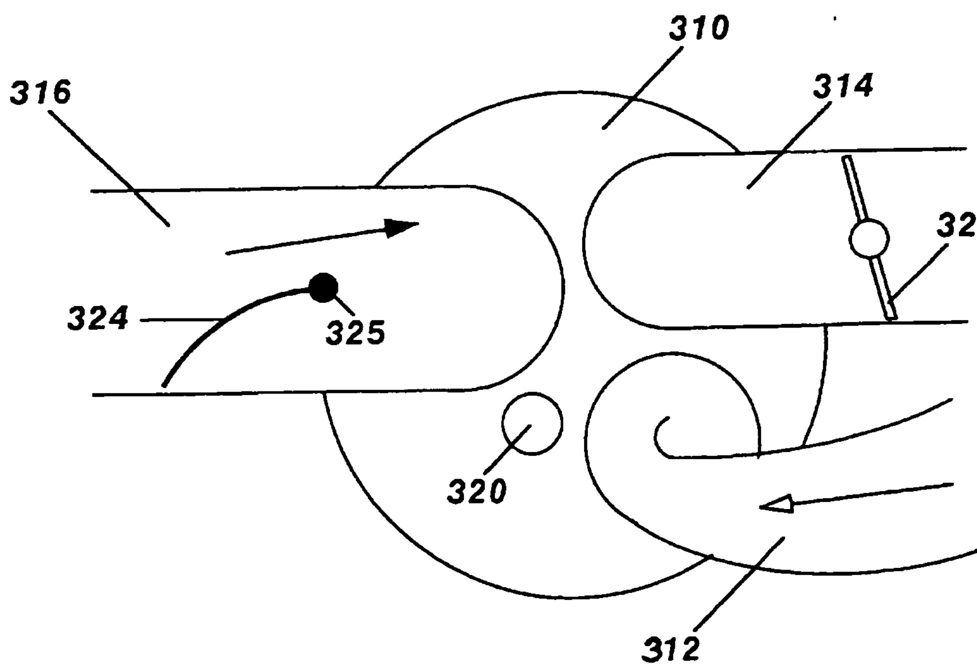


Fig.4



210
242
216
214
222
220
244
240
218
212

Fig.5



310
316
314
322
324
325
320
312

Fig.6

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INTERNAL COMBUSTION ENGINE

Field of the invention

The present invention relates to an internal combustion engine wherein each cylinder has one or more intake flow paths passing through one of more intake valves and configured to create a swirling motion in the intake charge in the combustion chamber, two exhaust flow paths passing through one or more exhaust valves for discharge of exhaust gases from the combustion chamber and means for delaying the closing time of at least one exhaust valve late into the intake stroke to increase internal exhaust gas recirculation (EGR).

Background of the invention

Engines with variable cam timing (VCT) have been proposed where the phasing of the camshaft relative to the crankshaft of the engine may be altered. In particular, the exhaust camshaft may be delayed under certain engine operating conditions so that the exhaust valves remain open during a significant period of the intake stroke at the same time as the intake valves are open. Consequently, exhaust gases are drawn back into the combustion chamber during the early part of the intake stroke at the same time as fresh air is drawn in. Depending of the setting of the VCT, a large quantity of exhaust gases may be recirculated back into the combustion chamber via this internal route, this being referred to as internal EGR to distinguish it from external EGR where exhaust gases are drawn into the intake system from the exhaust system by way of an external EGR pipe and EGR valve.

Both internal and external EGR are known to reduce NO_x emissions during combustion. Internal EGR has advantages

over external EGR in that the EGR gases are hotter and are therefore more effective for heating the cylinder charge. This is particularly important in a lean burn engine in which an increased charge temperature is required for stable combustion and increased exhaust gas temperature, the latter preventing the now obligatory catalytic converter in the exhaust system from getting too cold to function effectively. A further advantage of internal EGR over external EGR is that it is not drawn by manifold vacuum and a high degree of EGR dilution can be achieved even when the engine is unthrottled.

Internal EGR does however have a disadvantage when applied to an engine designed to operate with a swirling intake charge. In particular, it is known in lean burn engines to induce intentionally a strong swirling charge motion during the intake stroke to promote fast burn and charge stratification. In such engines, the internal EGR produces a different charge motion which weakens the swirl. Also, if the intake event is not delayed, the increased valve overlap with result in an adverse shortening of the time within the intake stroke during which a swirl can build up in intake charge. The combined result is that the swirl and the associated lean burn capability of the engine deteriorate as the internal EGR is increased.

Summary of the invention

With a view to mitigating the foregoing disadvantage, the present invention provides an internal combustion engine wherein each cylinder has one or more intake flow paths passing through one of more intake valves and configured to create a swirling motion in the intake charge in the combustion chamber, two exhaust flow paths passing through one or more exhaust valves for discharge of exhaust gases from the combustion chamber and means for delaying the closing time of at least one exhaust valve late into the

intake stroke to increase internal EGR, wherein means are provided for obstructing at least reverse gas flow along a first exhaust flow path during the intake stroke, and wherein the second exhaust flow path is configured to permit reverse flow of exhaust gases back towards the combustion chamber during the intake stroke, such reverse flow being directed to reinforce the swirling motion of the intake charge.

Delaying the closing of the time of the exhaust valve(s) will cause an increased valve overlap if the opening time of the intake valve(s) is not correspondingly delayed but the invention can also be applied to an engine with a single camshaft in which the overlap period is fixed.

If the only way for exhaust gases to escape from the combustion chamber in the forward direction during the exhaust period were by way of an exhaust flow path designed to promote swirl in the reverse direction during the intake stroke, then there would be an excessive flow resistance to the discharge of exhaust gases in the forward direction. Hence, the invention proposes the use of two exhaust flow paths which together are capable of discharging the full exhaust gas flow in the forward direction without creating an excessive back pressure in the combustion chamber. However, one of these flow paths can be blocked to reverse flow during the intake stroke so that the flow of internal EGR gases can only take place through the other flow path, which is designed to promote swirl.

The exhaust flow paths may either be defined by separate conduits with solid boundary walls between the paths or they may be adjacent gas flows along a common conduit. The engine may have one or more exhaust valves controlling the flow along the different flow paths and it is not essential for different exhaust valves to be associated with the different flow paths.

The means of restricting at least reverse gas flow can be a port butterfly valve or an engine exhaust poppet valve acting to restrict gas flow in both directions along the first of the exhaust flow paths, or it is may be a one-way valve, such as a flap valve, along the first flow path to restrict only reverse flow but not forward flow of exhaust gases.

In the present invention, instead of the swirl in the combustion chamber being weakened by the internal EGR gases, the reverse flow of exhaust gases is concentrated into a second exhaust flow path that strengthens the swirl induced by the intake port. Thus the lean burn capability of the engine is not compromised. Furthermore, the swirling exhaust gases may form a stratified hot gas layer, heating the intake charge and reducing the heat losses from the intake charge to the walls of the cylinder.

Brief description of the drawings

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of the intake and exhaust system of a cylinder of an engine in accordance with a first embodiment of the invention,

Figure 2 is a valve timing diagram for the exhaust and intake events of the engine in Figure 1,

Figure 3 is a view similar to that of Figure 1 showing a second embodiment of the invention,

Figure 4 is a valve timing diagram for the exhaust and intake events of the engine in Figure 3, and

Figures 5 and 6 are similar views to Figures 1 and 3 showing still further embodiments of the invention.

Detailed description of the drawings

Figure 1 shows a cylinder 10 having a spark plug 20, two intake ports 12, 14 and two exhaust ports 16, 18. The intake port 12 and the exhaust port 16 are designed as swirl ports. A butterfly valve 22 is arranged in the intake port 14 to deactivate the intake port 14 under certain engine operating conditions such as low and medium loads when a high swirl is required. The exhaust port 18 has two flap valves 24 arranged in back to back relation and fixed to a central spindle 25. Together the flap valves 24 act to permit exhaust gases to leave the combustion chamber but not to re-enter it.

The intake valves operate in synchronism with one another as do the exhaust valves so that their open events can be represented in Figure 2 as common intake and exhaust cam timing diagrams. The exhaust valves are closed later in the cycle as represented by the variable cam timing (VCT) arrow in Figure 2 when it is desired to increase internal EGR. In this figure the arc 28 represents the intake event and the arc 26 the exhaust event, the latter being variable by the VCT. The VCT will cause an increased overlap period during which both the intake and exhaust valves are open and the piston is in its induction stroke. The downward movement of the piston will draw gases into the combustion chamber both from the intake and exhaust systems, hence the internal recirculation of exhaust gases. Conventionally the back flow of EGR gases would interfere with the swirling motion created by the intake swirl port 16. However in the present embodiment the exhaust port 18 is automatically deactivated for reverse gas flow by the flap valves 24 and exhaust gases can only flow back into the combustion chamber 10 from the exhaust port 16 which, like the intake port 12, is designed to promote swirl.

At higher engine speeds and loads, the butterfly valve 22 is open and allows a larger mass of air to be drawn into the combustion chamber and at that time the internal EGR is discontinued by returning the VCT to its normal position.

The internal EGR in this way does not interfere with the swirling charge preparation at low and medium engine speeds and loads while the exhaust system as a whole is capable of supporting the full discharge of exhaust gases at high engine speeds and loads without presenting an excessive obstruction.

The embodiments of Figures 3, 5 and 6 have many components in common with the embodiment of Figure 1 and in order to avoid unnecessary repetition of description, like components had been allocated like reference numerals but augmented to the 100, 200 and 300 series respectively.

The embodiment of Figure 3 has the same intake system as that of Figure 1. However the exhaust system has a siamesed exhaust passage 118, the exhaust ports do not include a swirl port and the flap valves 24 are omitted. Instead of the flap valves 24, the exhaust poppet valves 116b and 116a are differently timed so that the exhaust valve 116a serves the function of preventing reverse gas flow during the increased overlap period during which only the closing time of the exhaust valve 116b is delayed by the VCT. Hence in Figure 4 the intake open event is represented by the arc 128, the event of the exhaust valve 116a is represented by the arc 126a which is fixed in relation to the intake valve event, and the event 126b of the exhaust valve 116b is the only one that is delayed by the VCT as represented by the VCT arrow.

The essential difference between the embodiments of Figure 1 and Figure 3 resides in the fact that instead of

just preventing back flow along the exhaust port 18 by use of flap valves 24, flow in both directions along one side of the exhaust passage 118 is obstructed by the closed exhaust poppet valve 116a to deactivate its associated first exhaust flow path entirely during the increased overlap period. By virtue of the direction of the second exhaust flow path associated with the exhaust valve 116b, reverse gas flow through it into the combustion chamber reinforces the swirl created by the intake swirl port 112 even though the exhaust port is not itself designed as a helical port.

In the embodiment of Figure 3 the cam operating the exhaust valve 116a can be mounted on the same camshaft carrying the cams of the intake valves while the cam operating the exhaust valve 116b is mounted on a separate camshaft the phase of which in relation to the intake camshaft is varied by the VCT.

The embodiment of Figure 5 once again has the same intake system as previously described and a siamesed exhaust port 240 leading to two exhaust flow paths 216, 218. The exhaust valves are once again operated in synchronism with one another, the valve timing diagram being the same as shown in Figure 2.

The flow path 218 is obstructed during the increased overlap period in the present embodiment by means of a butterfly valve 244 mounted on a spindle 242. One half of the butterfly valve 244 is arranged to obstruct the flow path 218 while the other half has a cut-out so as only partially to obstruct the flow path 216. Thus during the increased overlap period there will be little reverse gas flow along the flow path 218 but a high velocity reverse gas flow along the flow path 216 tending to promote swirl in the combustion chamber. At high engine loads in the present embodiment, the butterfly valve 244 is fully open to allow

totally unobstructed exhaust gas flow out of the combustion chamber.

The embodiment of Figure 6 differs from all previous embodiments in that a single exhaust valve and exhaust port 316 and a flap valve 324 mounted on a spindle 325 is used to separate the exhaust flow into two flow paths in the forward direction out of the combustion chamber, and to obstruct one of the flow paths in response to reverse gas flow as shown in the drawing. In this case, when the flap valve 324 is closed, it itself creates a high velocity in the flow of EGR gases that reinforces the swirl created by the intake port 312.

The flap valves of the embodiments of Figures 1 and 6 need not be hinged, as the reliability of hinges will be suspect in the hostile environment of an exhaust port. Instead they may be flexible flaps or reeds that bend to allow forward gas flow by yielding to the flow to avoid presenting an obstruction, and close in response to reverse gas flow to partially obstruct the back flow of gases towards the combustion chamber.

Though all the described embodiments involve an increase in the overlap between the intake and exhaust events, it will be clear that this is not essential to the implementation of the invention. Simultaneously phase shifting the intake and exhaust valves will also result in increased internal EGR, even though the extent of valve overlap would be unaffected.

CLAIMS

1. An internal combustion engine wherein each cylinder has one or more intake flow paths passing through one of more intake valves and configured to create a swirling motion in the intake charge in the combustion chamber, two exhaust flow paths passing through one or more exhaust valves for discharge of exhaust gases from the combustion chamber and means for delaying the closing time of at least one exhaust valve late into the intake stroke to increase internal EGR, wherein means are provided for obstructing at least reverse gas flow along a first exhaust flow path during the intake stroke, and wherein the second exhaust flow path is configured to permit reverse flow of exhaust gases back towards the combustion chamber during the intake stroke, such reverse flow being directed to reinforce the swirling motion of the intake charge.

2. An engine as claimed in claim 1, wherein the different exhaust flow paths are defined by separate conduits with solid boundary walls between the paths.

3. An engine as claimed in claim 1, wherein the different exhaust flow paths are formed by adjacent gas flows along a common conduit and not separated from one another by a solid boundary wall.

4. An engine as claimed in any preceding claim, wherein each cylinder has a single exhaust valve.

5. An engine as claimed in any of claims 1 to 3, wherein each cylinder has two or more exhaust valves.

6. An engine as claimed in any preceding claim, wherein the means for obstructing reverse gas flow along the first exhaust flow path comprises a flap valve.

7. An engine as claimed in any of claims 1 to 5, wherein the means for obstructing reverse gas flow along the first exhaust flow path comprises a butterfly valve.

8. An engine as claimed in claim 7, wherein the butterfly valve has a cut-out for allowing reverse gas flow along the second exhaust flow path while the first exhaust flow path is obstructed.

9. An engine as claimed in any one of claims 1 to 5, wherein the means for obstructing reverse gas flow along the first exhaust flow path comprises an exhaust poppet valve that is closed at different times from an exhaust poppet valve controlling the flow along the second exhaust flow path.

10. An engine as claimed in claim 1, wherein each cylinder comprises two exhaust valves that operate in synchronism with one another, the port of one of the exhaust valves including a one-way valve for obstructing reverse flow of exhaust gases, and the port of the other exhaust valve being designed as a helical swirl port for reverse flow of exhaust gases.

11. An engine as claimed in claim 1, wherein each cylinder has two exhaust valves, wherein one of the exhaust valves is operated in fixed phase relationship to the intake valves and only the closing time of the other exhaust valve is delayed to increase internal EGR.

12. An engine as claimed in claim 1, wherein the engine have two exhaust valves operated in synchronism with one another, a siamesed exhaust passage leading to both exhaust valves, a butterfly valve for obstructing a first flow path in the exhaust passage, and a cut-out in the butterfly valve for allowing reverse gas flow along a second

flow path in the exhaust passage when the first flow path is obstructed.

13. An engine as claimed in claim 1, wherein the engine has a single exhaust valve and exhaust port, and a flap valve partially obstructing the exhaust port to reverse gas flow and opening to allow unobstructed forward gas flow along the exhaust port.

14. An engine as claimed in any preceding claim, in which the means for delaying the closing time of at least one exhaust valve late into the intake stroke is operative to increase the overlap period between the intake and exhaust events.

15. An engine constructed, arranged and adapted to operate substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

The Patent Office

12

Application No: GB 9718578.9
Claims searched: 1-15

Examiner: David Glover
Date of search: 26 January 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F1B

Int Cl (Ed.6): F02B 17/00; F02D 13/02, 21/04, 21/08; F02F 1/42

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2263941	(Mercedes-Benz AG)	
A	GB 2114660	(Research Corporation)	
A	WO 85/05654	(Schüle)	
A	US 5161497	(Simko *et al*)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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